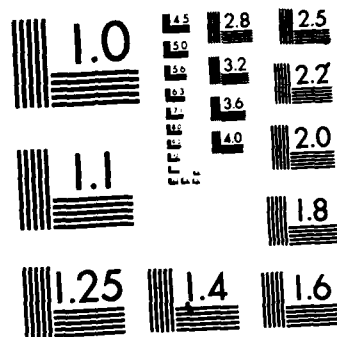


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REPORT NO. T12/86

AD-A172 752

**BODY COMPOSITION AND MUSCLE PERFORMANCE  
ASPECTS OF THE 1985 CFFS TEST**

**US ARMY RESEARCH INSTITUTE  
OF  
ENVIRONMENTAL MEDICINE  
Natick, Massachusetts**

**APRIL 1986**



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1. REPORT NUMBER T12/86	2. GOVT ACCESSION NO. ADA172	3. RECIPIENT'S CATALOG NUMBER 752
4. TITLE (and Subtitle) Body composition and muscle performance aspects of the 1985 CFFS test		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Marilyn A. Teves, James A. Vogel, Dawn E. Carlson, MAJ, AMSC and David D. Schnakenberg, COL, MS		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research Institute of Environmental Medicine, Natick, MA 01760-5007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Same as 9. above.		12. REPORT DATE April 1986
		13. NUMBER OF PAGES 38
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)  UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Combat field feeding system (CFFS), Meal Ready-to-Eat (MRE), Body composition, Muscle performance, tray pack ration, (T-ration)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A new combat field feeding system (CFFS) has been developed to provide soldiers with one to two hot meals at a minimal labor cost. The tray pack ration (T- ration) which requires no preparation or refrigeration and needs only to be heated is the ration under examination. Soldiers were tested before, during and after a 44 days field exercise to compare the T-ration to various combinations of existing feeding systems. Body composition and muscle strength and endurance were tested before and at days 1, 20 and 24 of the scenario. Skinfold and circumference techniques were used to estimate body composition. Isometric		

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A

Technical Report

No. T12/86

Body composition and muscle performance  
aspects of the 1985 CFFS test

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April 1986

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Natick, MA 01760-5007

## Foreword

With the development and decision to implement a new field ration feeding system in the Army, concerns developed as to its suitability over prolonged periods. Low consumption of these pre-prepared packaged rations during extended periods could lead to caloric and nutrient deficits, dehydration or other related problems that could eventually affect soldier performance. As the result of these concerns the Army Vice Chief of Staff directed that a study be carried out to address these questions. The study was conducted by the US Army Combat Developments Experimentation Center in collaboration with the US Army Research Institute of Environmental Medicine (USARIEM). USARIEM had responsibility for the nutritional and medical evaluation portion of the study. This evaluation was carried out by the Nutrition Research Task Force with the collaboration of the Heat Research, Health & Performance and Exercise Physiology Divisions. This report describes those aspects of the study concerned with body composition and muscular performance conducted by the Exercise Physiology Division.



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## ABSTRACT

A new combat field feeding system (CFFS) has been developed to provide soldiers with one to two hot meals at a minimal labor cost. The tras pack ration (T-ration) which requires no preparation or refrigeration and needs only to be heated is the ration under examination. Soldiers were tested before, during and after a 44 days field exercise to compare the T-ration to various combinations of existing feeding systems. Body composition and muscle strength and endurance were tested before and at days 1, 20 and 24 of the scenario. Skinfold and circumference techniques were used to estimate body composition. Isometric handgrip and 38 cm upright pull and maximum lift capacity were the strength measures collected. Muscular endurance was measured as holding time at 60% maximal handgrip strength. No significant differences were found between diet groups. Results showed an initial decrease in weight which tended to recover over time. This decrease was almost wholly accounted for by a decrease in percent body fat of 1.5% and 2.5% in men and women respectively. While no changes were found in arm muscle volume, women actually showed an increase in fat free mass. 38 cm upright pull increased across time in both men and women. None of the other strength or endurance measures changed significantly over time. It was concluded that consumption of the new CFFS for up to 44 days did not have an adverse impact upon body composition, muscular strength or endurance.

## I. Background

The US Army has developed and decided to implement a new Combat Field Feeding System (CFFS) to feed soldiers in the field. It was designed to be highly labor efficient, providing one or two hot meals per day with the remaining meals from operational rations. Hot meals will be composed of the new Tray Pack (T-ration). The Tray Pack ration consists of pre-packaged entrees, starches, vegetables and desserts that do not require refrigeration and merely need to be heated in the field before serving. T-rations will be augmented with B- and A-ration supplements as permitted by the tactical situation. The Meal-Ready-to-Eat (MRE) served as the operational ration of the CFFS.

Earlier testing of the MRE has shown acceptance for periods up to 34 days, however the MRE group lost significantly more weight (-3.7kg) than a control group (-2.1kg) who were fed two A-rations and one MRE during the same time period (1). Because of the potential impact of the CFFS on soldier performance, health and well being, the Vice Chief of Staff of the Army ordered a longer term evaluation with a more extensive analysis of the effects on the soldier. This directive led to a CFFS Force Development Test and Experimentation plan under the auspices of the US Army Combined Arms Combat Development Activity. As part of this test, the Army Surgeon General was tasked to address issues of nutritional adequacy and the effects of prolonged consumption on health and performance.

The Surgeon General's tasking was given to the US Army Research Institute of Environmental Medicine. The Exercise Physiology Division participated by addressing the two following issues under this tasking:

1. Do troops subsisting on CFFS rations for extended periods (42-49 days) maintain their nutritional status in terms of fat stores and muscle mass?

2. Will muscle strength and muscular endurance be maintained when soldiers subsist on CFFS rations for extended periods (42-49 days)?

This report contains the results of the investigations designed to answer these questions.

## II. Introduction

New rations for the soldier in the field are required to be nutritious, compact, lightweight and preparation free. Unfortunately the advanced technology that enables us to meet those requirements cannot ensure ration acceptance. The primary concern of any new ration is that it will be accepted and consumed by the soldier with adequate caloric and nutritional intake to meet the demands of the mission. This is particularly critical during periods of heavy physical activity lasting more than two weeks when the soldiers' energy demands are high. Studies have shown that caloric restriction combined with exercise results in a preservation of fat free mass and a reduction in fat mass (2). Prolonged reduced caloric intake could eventually lead to a loss of muscle mass which may affect performance of tasks limited by muscle mass.

Consumption of a new ration for a prolonged period may produce one of the following results:

1. Good ration acceptance, and maintenance of caloric intake, with no effect on body mass or performance.

2. Poor initial ration acceptance followed by a return to normal consumption driven by the caloric deficit. This temporary caloric deficit would produce some fat loss, but no lean tissue loss.

3. Poor ration acceptance accompanied by a decrease in physical activity commensurate with the lower caloric intake, with no loss of muscle mass.

4. Poor ration acceptance with no concomitant decrease in activity level, producing an energy deficit which may result in significant loss of muscle mass and eventual reduction in physical performance.

The purpose of USARIEM's portion of the CFFS study was to ascertain which of these possible alternatives occurs with prolonged implementation of the CFFS and to quantify the extent of any changes.

It is difficult to develop a hypothesis on this topic, as little previous research exists. The excellent studies on fasting, survival nutrition and use of diets for the treatment of obesity are not particularly germane to this study. Some earlier work was carried out by the British and US Armies on reduced caloric intake with the intent of reducing the weight of operational or combat ration that would be carried by the soldier on extended foot patrols. Consolazio and colleagues in 1965 (3) tested a series of high caloric density rations and concluded that 2000 kcal/day was sufficient for a 10-day combat patrol. Johnson, et al (4) in 1967 concluded that highly motivated men could perform well for ten days on 500 kcal/day. Oyen (5) reported that a trained Norwegian unit could endure four days of hard marching on a ration of 1000 kcal/day.

A previous study at Pohakuloa Training Area using two combat support companies examined the effect of 34 days of 3 MREs/day vs 2 A-rations and one MRE/day. Results indicated that both groups maintained their



nutritional status and were within normal range on all indices measured. While diet groups did not differ on a series of cognitive and psychomotor tests, no measures of physical strength or endurance were made. The percent of total body weight lost was 2% higher in the MRE than the control group due to a lower average daily caloric intake (MRE = 2189 kcal, control = 2950 kcal). The MRE group lost weight at a faster rate than the control group after the first half of the study. Were this trend to continue for an extended period, it is impossible to predict the effects on body composition and performance.

Two pertinent studies which included physical performance measures were carried out by the British Army (6, 7). The first (Glentroal trial) (6) found that a daily intake of 1,880 kcal during a strenuous 14 day patrol "imposed no physiological impediment to the maintenance of military efficiency". This diet met only half of their energy expenditure although they lost only an average of 2.2 kg of body weight. The second study (Exercise Desire, Malaysia) (7) also reduced caloric intake by one-half for 12 days but this time in a hot humid climate. This resulted in an average 3.9 kg weight loss but no decrement in performance.

The present CFFS experiment differs in several important ways from these earlier studies: adequate calories were made available, the test period lasted for over 40 days, laboratory measures of muscle strength and endurance were made and artillery personnel were utilized rather than infantrymen.

### III. Design and Methods

#### A. Design

The reader is referred to the CFFS Final Test Report (8) for complete details of the study. Pertinent design parameters are summarized here.

The study was conducted with personnel from the 25th Infantry Division Field Artillery. Forty soldiers were recruited for participation from each of six separate units to make up the six treatment groups (Table 1). One of the six groups consisted of all female soldiers. All soldiers were briefed and signed an informed consent form in accordance with approved human use procedures.

Four assessments of body composition and muscle strength were made during the course of the study. A control or pre-treatment measurement was made while the soldiers were in garrison at Schofield Barracks and will be referred to as test measurement "Pre". Immediately following the Pre measures, test personnel were transported to the Pohakuloa Training Area on the island of Hawaii and the ration treatments were begun. Measurements were again made on days 1, 20 and 44 of the ration feeding period referred to as T-1, T-20 and T-44, respectively. On the day of the tests the soldiers were transported by truck from their field bivouac sites to a laboratory located in huts in the cantonment area. Measurements were made early in the morning before breakfast.

#### B. Methods

##### 1. Body composition

In order to determine whether the various ration treatments influenced either the fat or muscle content of the body, estimates of percent body fat, total body fat, fat free mass (lean body mass) and

Table 1. Details of study design.

Treatment group	Gender	Treatment	Unit
1T	M	1T/2 MRE	A 1/8 FA
1TF	F	1T/2 MRE	DISCOM
2T	M	2T/2 MRE	B 7/8 FA
2TE	M	2T enhanced/MRE	C 7/8 FA
2B	M	2B/MRE	84th ENG
2A	M	2A/MRE	A 2/11 FA

upper arm muscle volume were made at the Pre, T-1, T-20 and T-44 test points. Measurements were made by two trained anthropometrists. Subjects were measured by the same anthropometrist at each test point.

Body weight was recorded in uniform and boots which was later corrected to nude weight. Body fat was estimated in the male groups by two different procedures. The first consisted of the Army's present skinfold caliper technique employing the Durnin and Womersley formulas (9). The Harpenden caliper was used to measure skinfold thickness at four locations (bicep, tricep, subscapular and suprailiac). The skinfold measures were transformed into body density, then into fat mass in kilograms (BF), or as a percentage of body weight (PBF). The formula is represented as:

$$PBF = [(4.95 - 1.1739 - 0.06227 \times \log \text{ sum } 4SF - 0.000555 \times \text{age}) - 4.5] \times 100.$$

The second body fat procedure for men consisted of the Army's new circumference technique(10) which will replace the skinfold procedure in 1986. This new method estimates body fat from measures of neck and abdominal circumference, and body height according to the following equation:

$$PBF = 46.892 - 68.678 \times \log_{10} \text{ height} + 76.462 \times \log_{10} (\text{abdominal-neck circumference})$$

Cloth anthropometric tapes were employed to measure circumference of the neck at a level just below the larynx and of the abdomen at a level coinciding with the midpoint of the navel. All equation input variables are in centimeters.

In the female group, BF was estimated only by the Durnin and Womersley skinfold procedure which employs the same skinfold sites as men but different equation constants.

$$PBF = [(4.95 - 1.1572 - 0.0647 \times \log \text{sum } 4SF - 0.00038 \times \text{age}) - 4.5] \times 100.$$

Fat free mass (FFM) was estimated by subtracting fat mass from total body weight.

The procedure of Wartenweiler, Hess, and Wuest (11) was employed to estimate the muscle volume of the upper right arm of each subject. This required the measurement of the bicep and tricep skinfolds, arm length, arm circumference and the diameter of the humerus epiphysis. Muscle volume was computed from the equations:

$$\text{muscle volume} = \text{muscle surface area} \times \text{arm length}$$

$$\text{muscle surface area} = (\text{diameter}^2 \text{ muscle} + \text{bone}) - (\text{diameter}^2 \text{ bone}) \times \pi/4$$

$$\text{bone diameter} = \text{diameter of epiphysis} / 3.1$$

$$\text{muscle} + \text{bone diameter} = (\text{upper arm circumference} / \pi) - \\ (\text{bicep skinfold} + \text{tricep skinfold})$$

## 2. Muscle performance

In order to determine whether the various ration treatments influenced muscular performance, several measures of muscle strength and lifting capacity were made. These consisted of maximal handgrip force, handgrip force endurance, upright pull force and maximal lift capacity. Each measurement was taken by the same technician at each test point.

Maximal isometric handgrip force was measured with a specially designed ergometer built in this laboratory (12). The handgrip ergometer was adjusted to produce an angle of 150° at the third metacarpalphalangeal joint and 110° at the proximal interphalangeal

joint of the third finger. The maximal force that could be exerted in three trials was recorded with an electronic load cell transducer and digital readout which has an accuracy of  $\pm 0.5\%$ .

In one-half of the subjects, the additional measure of the time that a subject could maintain a force of 60% of the previously measured maximal handgrip force was recorded. An indicator was adjusted on the face of an analog meter to indicate the 60% level. When the subject could no longer maintain the force at this level and the meter needle dropped below the 60% indicator, the test was terminated and the duration was recorded in seconds.

Maximal isometric upright pull force was measured with equipment and procedures developed previously in this laboratory (13). The subject stood in a squatting position over a load cell transducer mounted in a platform and grasped a bar attached by a 38cm cable to the transducer. While maintaining a safe body posture, the subject exerted maximal isometric pull force in a vertical direction for each of three trials. The transducer output was recorded on a digital readout. The reliability coefficient over three trials is 0.97.

The maximal lift capacity procedure and equipment are described in an earlier report (14). The test employed a weight machine with weight plates attached to a carriage which moved up and down vertical rails. The subject raised the carriage via attached handles. The subject began at a weight of 18 kg and 9 kg were added to each successive trial until the subject was unable to lift the load in a smooth and safe action to the height of 132cm.

#### IV. Results

##### A. Body Composition

Energy intake was generally maintained and only modest weight loss was observed during the study as summarized in Table 2. The greatest average weight loss (2.9%) was observed in group 2B while group 1TF showed the smallest loss. The lowest incidence of individual weight loss was in group 2A while the highest incidence was in group 2B. All groups except 2B exhibited a trend for maximum weight loss to occur mid-way in the study (T-20 to T-24) and thereafter tending to partially recover by the end of the study. The reader is referred to the test report (8) for further details on both weight loss and energy intake.

Examination of body fat values in the male groups determined by the two separate techniques (skinfold and circumference) demonstrated considerably better consistency and reproducibility with the circumference technique. Data presented here on the five male groups therefore represents only the data obtained by the circumference technique.

Group means  $\pm$  standard deviations at each test point are presented in Tables 3-6 for male subject groups and Table 7 for the female group. The data were analyzed using a repeated measures analysis of variance (ANOVA) with a preset alpha level of  $p < .01$ . The female data were analyzed separately from the male data due to known differences in body composition. These differences were confirmed by a one way ANOVA across the six groups for pre-test data. Females had significantly less FFM, and more BF.

Table 2. Body weight (kg) by treatment group and time of measurement.

Group	n	Pre		T-1			T-20			T-44	
		Mean	SD	Mean	SD	%Δ *	Mean	SD	%Δ *	Mean	SD
2T	33	76.5	10.5	76.5	10.5	-0.3	75.2	9.8	-2.0	75.5	9.5
2TE	36	79.8	11.1	79.7	11.0	-0.1	78.3	10.4	-1.9	78.5	10.0
1T	36	77.6	8.9	77.5	9.1	-0.1	76.3	8.2	-1.7	75.8	7.9
1TF	36	64.4	7.9	64.4	7.6	0.0	63.3	7.6	-1.7	63.9	7.6
2A	33	76.2	10.6	75.6	10.6	-0.8	74.6	10.2	-2.1	75.1	9.8
2B	29	75.3	11.3	75.1	11.1	-0.3	73.7	10.3	-2.1	73.1	9.9
All	203	74.9	11.2	74.7	11.1	-0.3	73.5	10.6	-1.9	73.6	10.2

\* percent change from Pre measurement.



Table 3. Percent body fat of males determined by circumference technique of each treatment group at each time of measurement (Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	19.0 $\pm$ 5.6	18.9 $\pm$ 5.9	17.7 $\pm$ 5.2	17.6 $\pm$ 5.1
2TE	36	20.0 $\pm$ 5.1	19.7 $\pm$ 5.1	18.7 $\pm$ 4.4	18.3 $\pm$ 4.4
1T	36	18.3 $\pm$ 4.4	18.2 $\pm$ 4.9	17.4 $\pm$ 4.0	16.7 $\pm$ 3.5
2A	33	19.2 $\pm$ 4.6	18.5 $\pm$ 4.6	17.6 $\pm$ 4.3	17.2 $\pm$ 4.1
2B	29	20.0 $\pm$ 4.7	19.9 $\pm$ 5.1	19.0 $\pm$ 4.5	17.8 $\pm$ 4.1
All Gps.	167	19.3 $\pm$ 4.9	19.0 $\pm$ 5.1	18.1 $\pm$ 4.5	17.5 $\pm$ 4.2

F value for group comparison = 0.69

F value for repeated measures = 76.26

Table 4. Fat free mass (kg) of males determined by circumference technique of each treatment group at each time of measurement (Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	61.8 $\pm$ 7.0	61.7 $\pm$ 6.9	61.6 $\pm$ 7.0	62.0 $\pm$ 6.8
2TE	36	63.5 $\pm$ 6.9	63.7 $\pm$ 7.3	63.4 $\pm$ 7.1	63.9 $\pm$ 7.2
1T	36	63.3 $\pm$ 6.8	63.2 $\pm$ 6.9	63.0 $\pm$ 6.8	63.2 $\pm$ 6.8
2A	33	61.3 $\pm$ 6.6	61.2 $\pm$ 6.6	61.1 $\pm$ 6.5	61.9 $\pm$ 6.3
2B	29	59.8 $\pm$ 6.7	59.8 $\pm$ 6.6	59.4 $\pm$ 6.4	59.9 $\pm$ 6.7
All Gps.	167	62.0 $\pm$ 6.8	62.0 $\pm$ 7.0	61.8 $\pm$ 6.8	62.3 $\pm$ 6.8

F value for group comparison = 1.66

F value for repeated measures = 7.46

Table 5. Body fat (kg) of males determined by circumference technique of each treatment group at each time of measurement (Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	14.9 $\pm$ 5.7	14.8 $\pm$ 5.9	13.6 $\pm$ 4.9	13.5 $\pm$ 4.8
2TE	36	16.3 $\pm$ 5.9	16.0 $\pm$ 5.7	14.9 $\pm$ 5.0	14.6 $\pm$ 4.8
1T	36	14.3 $\pm$ 4.4	14.2 $\pm$ 4.8	13.3 $\pm$ 3.7	12.7 $\pm$ 3.1
2A	33	15.0 $\pm$ 5.1	14.4 $\pm$ 5.1	13.5 $\pm$ 4.6	13.2 $\pm$ 4.4
2B	29	15.4 $\pm$ 5.6	15.3 $\pm$ 5.8	14.3 $\pm$ 5.1	13.2 $\pm$ 4.4
All Gps.	167	15.2 $\pm$ 5.3	14.9 $\pm$ 5.4	13.9 $\pm$ 4.7	13.4 $\pm$ 4.3

F value for group comparison = 0.71

F value for repeated measures = 85.18

Table 6. Upper arm muscle volume (liters) of males by treatment group and time of measurement (Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	1.690 $\pm$ 0.309	1.777 $\pm$ 0.336	1.756 $\pm$ 0.334	1.797 $\pm$ 0.3
2TE	36	1.858 $\pm$ 0.296	1.867 $\pm$ 0.394	1.870 $\pm$ 0.300	1.894 $\pm$ 0.3
1T	36	1.930 $\pm$ 0.428	1.985 $\pm$ 0.450	1.936 $\pm$ 0.392	1.953 $\pm$ 0.4
2A	33	1.796 $\pm$ 0.434	1.779 $\pm$ 0.437	1.811 $\pm$ 0.421	1.859 $\pm$ 0.4
2B	29	1.768 $\pm$ 0.347	1.742 $\pm$ 0.344	1.736 $\pm$ 0.317	1.728 $\pm$ 0.3
All Gps	167	1.812 $\pm$ 0.372	1.835 $\pm$ 0.402	1.826 $\pm$ 0.360	1.852 $\pm$ 0.3

F value for group comparison = 1.61

F value for repeated measures = 4.36

Table 7. Body composition as a function of time in female Group 1TF

Group	n	Repeated Measures								F-value
		Pre		T-1		T-20		T-44		
Percent body fat	36	28.6	$\pm 3.9$	26.8	$\pm 4.1$	26.2	$\pm 4.2$	25.5	$\pm 4.1$	63.33
Fat free mass (kg)	36	45.9	$\pm 5.2$	47.0	$\pm 4.9$	46.6	$\pm 5.0$	47.5	$\pm 4.9$	24.72
Fat mass (kg)	36	18.5	$\pm 4.0$	17.4	$\pm 4.0$	16.7	$\pm 4.0$	16.4	$\pm 4.1$	44.09
Upper arm muscle vol, ( L)	36	.995	$\pm .344$	.941	$\pm .236$	.960	$\pm .174$	1.007	$\pm .187$	0.57

An ANOV of each variable measured at four separate occasions for each of the five male diet groups revealed no significant differences between diet groups on any of the body composition measures. The differences across time were significant for each of the variables measured, but none of these differences were able to meet the criteria for significance on a post hoc test. There was, however, a trend for body fat to decrease with time while fat free mass held constant as depicted in Figure 1.

As already noted, the largest drop in body weight occurred midway in the study near the T-20 measurement. Further examination of these data indicated that, overall, loss in body weight was highly correlated with loss in body fat ( $r = 0.78$ ,  $p < .01$ ) as illustrated in Figure 2. This is further demonstrated in Table 8 in which the male group data are divided into deciles based on body weight. The changes in body fat and fat free mass are listed for each of these deciles. This analysis indicated that of those who lost a significant amount of weight (first two deciles), two-thirds of the loss was from fat stores and one-third from fat free mass. On the other hand, of those who gained weight (10th decile), all of their gain came from an increase in fat free mass.

Table 9 examines the loss in body weight and BF as a function of initial level of adiposity (PBF) in male subjects. The data are divided into quartiles by PBF at the initial Pre test point. This clearly shows that the amount of total body and fat weight lost was positively related to higher initial levels of percent body fat.

Significant differences were found across time in female body composition as determined by skinfolds. Significant decreases from T1-T44 were found in percent body fat and absolute body fat (kg) while a

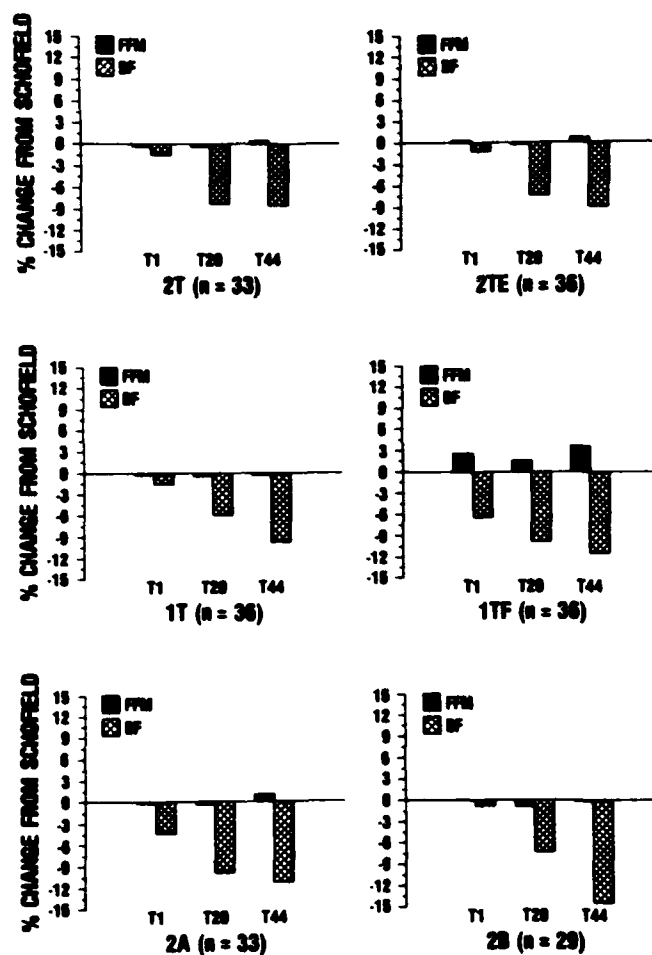


Figure 1. Percent change in body fat and fat free mass from Pre test by test point and dietary group.

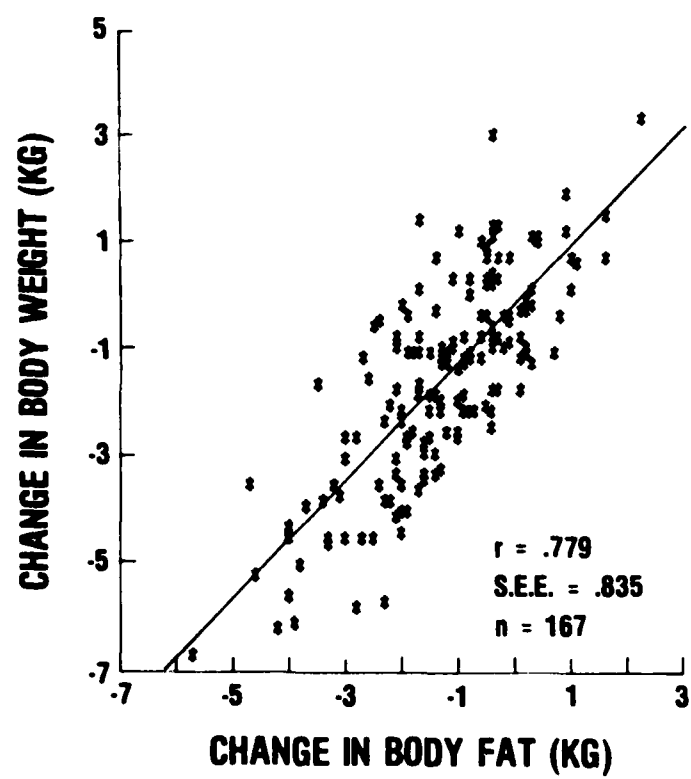


Figure 2. Scatter plot of male group data for body weight change versus body fat change in kilograms



Table 8. Relationship of body weight changes (Pre to T-20) to changes in body fat and free mass. Data are shown divided into deciles by absolute weight change along with correlation coefficients between weight change and body fat and fat free mass change, respectively. Male group data only.

Body wt change decile	Body wt $\Delta$ x (kg) (n)		Body fat $\Delta$ x (kg)	FFM $\Delta$ x (kg)	Correlation Coefficient Body wt $\Delta$ BF $\Delta$ FFM $\Delta$	
10th	- 5.13	(16)	- 3.51	- 1.61	.52	.31
20	- 3.68	(16)	- 2.56	- 1.12	.00	.23
30	- 2.77	(18)	- 1.73	- 1.04	.24	.20
40	- 2.02	(17)	- 1.32	- 0.61	.21	- .03
50	- 1.47	(15)	- 1.28	- 0.19	.25	- .03
60	- 1.01	(22)	- 0.95	- 0.08	.02	.07
70	- 0.70	(13)	- 0.87	+ 0.16	- .37	.49
80	- 0.24	(17)	- 0.45	+ 0.22	- .1	- .05
90	- 0.43	(15)	- 0.22	+ 0.66	.39	- .13
100	+ 1.46	(18)	+ 0.05	+ 1.40	.39	.34
Total	- 1.50	(167)	- 1.27	- 0.22	.78	.72

Table 9. Change (Pre to T-20) in male body weight and body fat as a function of initial level of adiposity. Data presented in percent body fat quartiles at time of pre-test measure.

Pre % body fat quartile	Pre to T-20	
	$\Delta$ in body wt. (kg)	$\Delta$ in body fat (kg)
< 15.7	0.29	0.25
15.8 - 18.6	0.88	0.95
18.7 - 22.7	1.83	1.62
> 22.7	3.06	2.31

significant increase in fat free mass was found between pre-test and all field measurements (T1, T20 and T44) and from T20 to T44.

#### B. Muscle performance

Group mean  $\pm$  standard deviation at each test point are presented in Tables 10-13 for male subject groups and Table 14 for the female group. These data were also analyzed using a repeated measures analysis of variance (ANOVA) with a preset alpha level of  $p < .01$ . The female data were again analyzed separately from the male data due to known differences in muscular strength. These differences were confirmed by a one way ANOVA across the six groups for pre-test data. Females were significantly lower than males on handgrip strength, maximal lift capacity and 38cm upright pull.

An ANOVA of each variable measured at four separate occasions for each of the five male diet groups revealed no significant differences between diet groups on any of the muscle strength/endurance measures. The differences across time were significant for each of the variables measured, but none of these differences with the exception of 38cm upright pull, were able to meet the criteria for significance on a post hoc test.

The 38cm upright pull test demonstrated significant increases from pre test to T20 and T44 in males. The testing position utilized when performing the 38cm upright pull is difficult to assume and is critical to maximal force output on the task. The sharp increase in strength from pre test to T1, which averaged 12.8% for all groups combined was probably due to a learning effect. Further observed increases in strength of approximately 4% may have been due to intensity of exercise

Table 10. Maximal isometric handgrip force (kg) of males by treatment group and time of measurement ( Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	57.2 $\pm$ 8.3	57.9 $\pm$ 7.8	57.8 $\pm$ 8.2	57.6 $\pm$ 9.7
2TE	36	60.3 $\pm$ 8.9	60.3 $\pm$ 8.6	59.9 $\pm$ 10.0	58.9 $\pm$ 9.4
1T	36	59.9 $\pm$ 8.6	63.1 $\pm$ 11.6	63.6 $\pm$ 10.2	61.9 $\pm$ 9.6
2A	33	55.2 $\pm$ 8.2	58.6 $\pm$ 9.2	57.9 $\pm$ 10.2	58.9 $\pm$ 9.1
2B	29	54.7 $\pm$ 6.9	56.4 $\pm$ 7.7	56.3 $\pm$ 8.4	55.6 $\pm$ 8.1
All Gps.	167	57.6 $\pm$ 8.5	59.4 $\pm$ 9.3	59.3 $\pm$ 9.7	58.7 $\pm$ 9.3

F value for group differences = 2.78

F value for repeated measures = 7.46

Table 11. Isometric handgrip endurance time (seconds) of males at 60% of maximal force ( Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	19	50.6 $\pm$ 15.8	61.1 $\pm$ 17.8	53.7 $\pm$ 17.3	53.3 $\pm$ 16.1
2TE	17	51.9 $\pm$ 18.9	59.2 $\pm$ 20.4	61.6 $\pm$ 25.7	57.1 $\pm$ 22.3
1T	17	49.9 $\pm$ 13.7	47.1 $\pm$ 16.4	55.1 $\pm$ 21.4	47.2 $\pm$ 15.8
2A	17	46.1 $\pm$ 10.3	58.2 $\pm$ 16.6	51.9 $\pm$ 18.9	53.8 $\pm$ 14.0
2B	14	58.3 $\pm$ 14.8	52.3 $\pm$ 13.9	55.6 $\pm$ 17.1	49.1 $\pm$ 19.1
All Gps.	84	51.1 $\pm$ 15.1	55.8 $\pm$ 17.7	55.6 $\pm$ 20.1	52.2 $\pm$ 17.5

F value for group comparison = 0.56

F value for repeated measures = 3.22

Table 12. Maximal lift capacity (kg) of males (Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	56.9 $\pm$ 11.3	59.2 $\pm$ 11.8	62.9 $\pm$ 12.3	62.3 $\pm$ 12.3
2TE	34	65.7 $\pm$ 13.7	65.2 $\pm$ 13.5	66.9 $\pm$ 13.2	68.8 $\pm$ 12.1
1T	35	64.5 $\pm$ 13.9	68.7 $\pm$ 14.0	70.9 $\pm$ 12.1	72.1 $\pm$ 12.7
2A	32	67.3 $\pm$ 13.5	65.8 $\pm$ 13.5	68.0 $\pm$ 14.3	70.3 $\pm$ 13.5
2B	29	62.9 $\pm$ 12.6	63.1 $\pm$ 12.6	65.6 $\pm$ 13.3	65.7 $\pm$ 12.4
All Gps.	163	63.5 $\pm$ 13.4	64.5 $\pm$ 13.3	66.9 $\pm$ 13.1	68.0 $\pm$ 13.0

F value for group comparison = 2.51

F value for repeated measures 27.04

Table 13. Maximal isometric 38 cm upright pull force (kg) of males(Mean  $\pm$  SD).

Group	n	Pre	T-1	T-20	T-44
2T	33	134.0 $\pm$ 28.3	138.0 $\pm$ 28.6	142.3 $\pm$ 31.0	148.6 $\pm$ 38.7
2TE	34	139.1 $\pm$ 24.8	151.4 $\pm$ 31.9	155.1 $\pm$ 32.2	150.5 $\pm$ 31.9
1T	35	127.8 $\pm$ 20.1	151.7 $\pm$ 25.2	157.5 $\pm$ 24.3	158.7 $\pm$ 23.9
2A	32	120.6 $\pm$ 26.3	136.4 $\pm$ 26.1	140.9 $\pm$ 30.6	144.9 $\pm$ 27.8
2B	29	115.6 $\pm$ 15.8	133.9 $\pm$ 19.1	140.9 $\pm$ 26.3	138.8 $\pm$ 21.9
All Gps.	163	127.8 $\pm$ 24.8	142.7 $\pm$ 27.5	147.8 $\pm$ 29.7	148.8 $\pm$ 29.8

F value for group comparison = 2.77

F value for repeated measures = 19.27

during the field scenario. A series of one-way ANOVs revealed significant differences among male diet groups at each measurement. These group differences did not show a consistent pattern of change across time and are probably a reflection of the variability of the 38cm upright pull measure.

Although not statistically significant, there was a trend for maximal lift capacity to increase with time, averaging 7% increase from Pre-test to T-44. This undoubtedly represents some technique practice effect as well as some minimal increase in actual strength. Figure 3 depicts these trends.

The females did not change significantly from pre test to T44 in handgrip strength, handgrip endurance time or maximum lift capacity (Table 14). Similar to the male 38 cm upright pull strength, the females increased significantly from pre test to T1, T20 and T44. As mentioned earlier, this rapid initial increase can be attributed to a learning effect followed by a levelling off in score.

Although diet group had no effect on muscle strength, it was postulated that individuals with the greatest weight loss may exhibit fluctuations in strength not seen in those losing less weight. Male subjects were placed into deciles based on weight lost from T1 to T44. The mean change in handgrip and maximum lift capacity from T1 to T44 for each decile was determined and a one way ANOV used to compare the deciles. Handgrip strength was not affected by weight loss. While there was a significant difference in MLC increase between weight loss deciles, the increases in MLC did not show a consistent change with weight loss as evidenced in Figure 4.



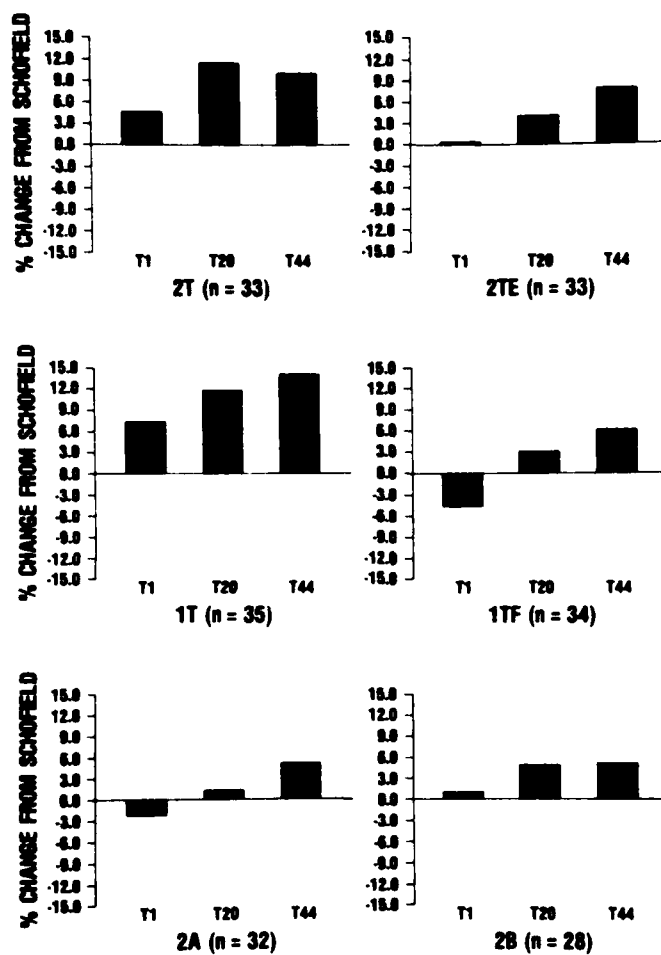


Figure 3. Percent change in maximum lift capacity from Pre test as a function of dietary group.

Table 14. Muscular strength as a function of time in female Group 1TF (Mean  $\pm$  SD).

Variable	n	Pre	T-1	T-20	T-44	F
Max handgrip force (kg)	36	36.4 $\pm$ 4.9	37.9 $\pm$ 6.1	38.7 $\pm$ 6.1	37.8 $\pm$ 6.3	0.97
Handgrip endurance time (sec)	16	52.4 $\pm$ 25.0	60.5 $\pm$ 18.8	65.9 $\pm$ 23.7	58.3 $\pm$ 18.2	1.08
38 cm pull (kg)	35	79.7 $\pm$ 13.0	90.3 $\pm$ 19.4	94.9 $\pm$ 20.5	98.9 $\pm$ 18.5	7.40
Max lift capacity (kg)	35	36.1 $\pm$ 7.24	33.7 $\pm$ 7.4	36.3 $\pm$ 7.8	38.0 $\pm$ 8.9	1.81

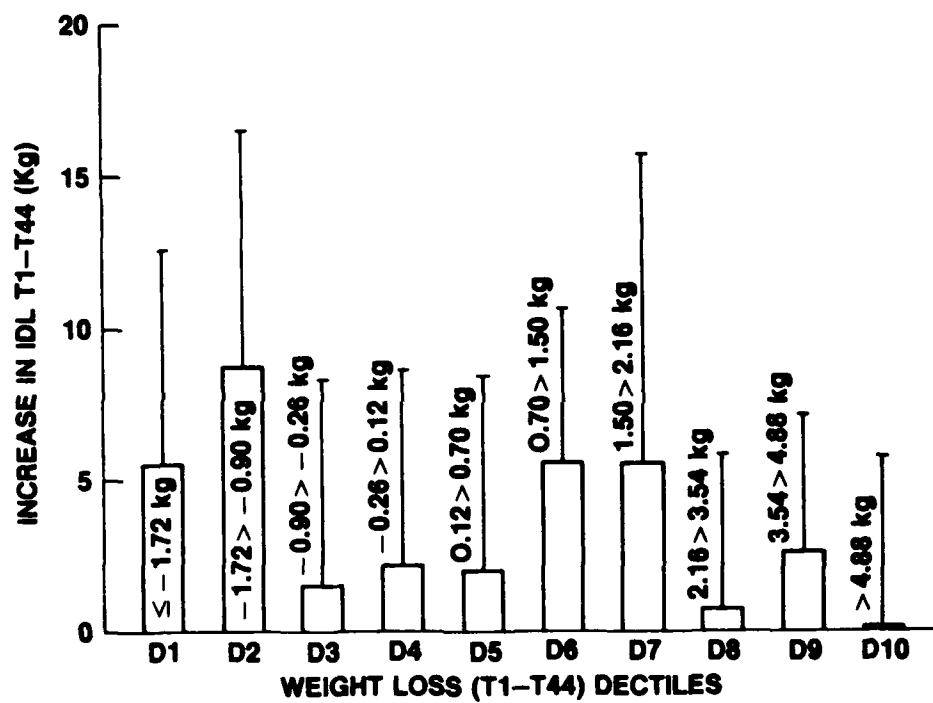


Figure 4. Increase in maximal lift capacity from T1 - T44 by weight loss decile.

In order to examine the relationship between muscle strength and body composition, the males were divided into deciles based on handgrip strength and maximum lift capacity. Means of body composition measures were obtained for each decile and an ANOV used to examine differences. Handgrip deciles did not differ in body fat or percent body fat, however the first six deciles had significantly lower fat free mass than the highest 3-4 deciles. Due to the nature of the lifting capacity test it was not possible to divide the data into 10 deciles and only eight separate groups were formed. The groups based on lifting capacity revealed no significant differences in percent body fat. The first two lifting capacity deciles had significantly lower fat free mass than deciles nine and ten and less body fat than deciles eight and nine. These results are presented in Table 15 and demonstrate the obvious importance of fat free mass in producing force. It is interesting to note that the males with greater lifting capacity also tended to have greater amounts of body fat. In other words maximal lifting capacity is more dependent upon body size and weight than simply FFM as was handgrip. These results are in agreement with a large cross sectional study of Army body composition and performance (10).

#### V. Discussion

Of the four possible outcomes suggested in the introduction, outcome number two most closely agrees with the observed results, that is, there was an initial mild decrease in consumption of the test rations with a concomitant modest reduction in body weight. Body weight tended to recover with time as caloric intake normalized. The modest decline in weight was almost entirely due to loss in body fat, not muscle mass, and therefore there was no decrement in muscular performance.

Table 15. Body composition based on handgrip and maximum lift capacity deciles.

Handgrip Decile (kg)		Fat Free Mass(kg)	Maximum Lift Capacity Decile		Fat Free Mass(kg)	Body Fat (kg)
10th	≤46.9	56.7 <sup>1</sup>	10th	≤50	55.1 <sup>2</sup>	12.0 <sup>3</sup>
20th	46.9>53.0	59.5	20th	50>54	61.1	14.4
30th	53.0>55.0	60.5	30&40th	54>59	61.1	13.5
40th	55.0>56.5	59.9				
50th	56.5>59.0	60.2	50th	59>64	62.1	16.0
60th	59.0>60.9	58.9				
70th	60.9>63.5	63.8	60&70th	64>68	61.6	14.2
80th	63.5>67.0	67.1	80th	68>77	63.8	17.3
90th	67.0>70.7	67.5	90th	77>86	67.6	18.9
100th	≥70.7	65.8	100th	≥86	70.5	16.5

1. 10th-60th percentiles significantly different from 80th-100th.
2. 10th percentile significantly less than all others. 20th-70th percentiles significantly different from 90th and 100th.
3. 10th-70th percentiles significantly different from 80th and 90th percentile.

There was no evidence of a decrement in arm muscle volume or fat free mass in the male groups, and an actual increase in fat free mass in the female group, as the result of dietary treatment over time. The trend for decreases in body fat in all groups is in agreement with the body weight changes observed but would not be interpreted as an undesirable response in light of the very adequate body fat stores at the beginning of the study, i.e., average of 19% body fat in males and 28% in females. Thus, the mean body fat stores at the end of the study of 17.5% for males and 25.5% for females can be considered well within normal ranges for these age groups. Table 16 presents body composition data from other US Army populations for comparison.

The increase in fat free mass in females may reflect a greater intensity of muscular activity (other than running) than they are accustomed to in garrison, thus providing a stimulus for muscle hypertrophy, although this was not reflected in upper arm muscle volume. This finding in women is similar to that found in female basic trainees; an increase in fat free mass and decrease in body fat during the course of eight weeks of training (15).

There was no evidence in any of the four muscle strength/endurance measurements made of any decrement as the result of dietary treatment over time. This agrees with the report of Taylor, et al (19) who reported that performance capacity is not adversely affected with a weight loss of up to 10% if ketosis, dehydration and hypoglycemia are avoided. In this study groups actually showed small increases in 38cm upright pull strength and maximal lift capacity that are probably primarily attributable to learning or improvement in technique and to a lesser degree in an actual increase in strength. This is in agreement with the findings that there were no significant decreases in arm muscle volume or total body fat free mass. Table 17 compares values from this study with previously reported Army samples.

In summary, the modest loss in body weight that occurred in the test ration groups involving various combinations of tray packs and MREs, was due to a decrease in body fat with no measurable decline in muscle mass. In agreement with this there was no evidence of any decrement in muscular performance. Thus, we conclude that the consumption of one or two tray packs plus MREs for up to 44 days in an operational field setting has no adverse effect on nutritional status (in terms of muscle mass and body fat stores) or muscular performance.

Table 16. Comparison of present data with other US Army samples

<u>Subjects (Reference)</u>	<u>% Body Fat</u>	
	<u>Males</u>	<u>Females</u>
1. Basic recruits - pre training	16.3	28.2
- post training	14.5	26.2
(Patton, et al. Aviat. Space Env. Med 51:492, 1980)		
2. Basic recruits - pre training		
Age 17-20	15.3	27.7
21-25	16.1	28.8
26-30	18.1	28.3
31-35	22.4	31.0
(Knapik, et al. Aviat. Space Env. Med 54:223, 1983)		
3. Infantry Units		
Age 17-20	15.8	
21-25	17.9	
26-30	19.3	
31-35	20.0	
40-43	25.8	
44-47	26.5	
48-51	26.5	
(Vogel, et al. NATO Meeting, 1978, Patton, et al. Aviat. Space Env. Med 54:138, 1983).		
4. Present study (Pre values)	19.3	28.6



Table 17. Comparison of present muscle strength data with previous US Army study samples.

Study Sample	(Ref)	Maximal Isometric		Maximal Lift (kg)
		Handgrip (kg)	Upright Pull (kg)	
<u>Males</u>				
1. Recruits	14	52.6	148.8	65.5
2. Infantry	17	56.2	130.6	-
3. Infantry	18	54.0	138.0	57.6
4. Current Study		57.6	127.8	63.5
<u>Females</u>				
1. Recruits	18	34.1	83.7	32.5
2. Current Study		36.4	79.7	36.1

## HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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